Final Report

Development of Technology for Modernizing Depot Handling of Fasteners

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Defense Logistics Agency
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Cameron Station, VA 22304-6100

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This report the results of research conducted for the Defense Logistics Agency (DLA) in the development of a technology for modernizing depot handling of fasteners. The proposed technology would aid in performing a limited technical inspection of the geometric and metallurgical qualities of fasteners as they are received from manufacturers of distributions. The technology would **validate** received material (providing technical data to assure that the receuved material corresponds to the contract that was issued) and help **identify** stock (providing a National Stock Number for material that is received with improper or absent documentation).

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Executive Summary

This report presents the results of research conducted for the Defense Logistics Agency (DLA) in the development of a technology for modernizing depot handling of fasteners. The proposed technology would aid in performing a limited technical inspection of the geometric and metallurgical qualities of fasteners as they are received from manufacturers or distributors. The technology would *validate* received material (providing technical data to assure that the received material corresponds to the contract that was issued) and help *identify* stock (providing a National Stock Number for material that is received with improper or absent documentation).

The investigation has revealed that improving the technical support tools for receiving inspection at depots can have a large impact on the problems of handling fasteners in the DLA inventory. Inspectors must handle new procurement and customer returns. Both forms of shipment often require the inspector to verify that the item corresponds to the contract number and that it is in usable condition. Inspectors typically have a few simple measurement tools to verify the conformability of thousands of different fasteners. Plating type, material composition and geometry are often impossible to quantify. As a result, the identification of an item is very tedious, if not impossible. Many receipts are either misidentified and placed in inventory or targeted for disposal.

The proposed plan for Phase II of this research effort calls for the development of a tool to improve the receiving inspection process for fasteners at depots. The corresponding proposal *Development of a Receiving Inspection Item Identifier/Validator* serves as an appendix to this report. The proposed technology development can have a significant impact on the problems of handling fasteners in the DLA inventory. There is a large potential cost savings that could result from supplying technical tools to aid in the receiving inspection process.

The DoD inventory has been effectively encoded in a variety of different database software systems. In the proposed research, these database capabilities could be integrated with technical tools for identifying metallurgy, plating and geometry. These technologies can be assembled into a system to quickly and accurately identify the technical data associated with a particular fastener. This data can provide parametric data input into a database and identify a National Stock Number, flag non-conforming material or avoid the unnecessary disposal of costly components.

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1. Introduction

1.1 Background

This research investigated a technology for modernizing depot handling of fasteners by performing a limited technical inspection of the geometric and metallurgical qualities of fasteners as they are received from manufacturers or distributors. The technology would *validate* received material (providing technical data to assure that the received material corresponds to the contract that was issued) and help *identify* stock (providing a National Stock Number for material that is received with improper or absent documentation).

The original motivation for this research was found in the widely publicized problems with non-conforming fasteners sold to both the military and commercial industry. Most of these problems were related to a high strength designation part, the SAE Grade 8.0. In the late 1980s, tests on samples from various lots in depot inventories showed a non-conformance rate to Grade 8.0 specifications that called for costly freezing of inventory and disposing of an enormous dollar volume of fasteners.

The objectives of this research were defined by the proposal *Development of Technology for Modernizing Depot Handling of Fasteners for Detection of Counterfeits and Inventory Control* submitted by the University of Detroit in response to PRDA 90-01 released by the Defense Logistics Agency. The University of Detroit (now the University of Detroit Mercy) was awarded contract DLA900-91-C-1643 to conduct a Phase I research program to investigate the problem described in the proposal and present a Phase II research proposal to implement a prototype of the proposed solution strategy.

1.2 Objectives of the Research

The goal of this research was to develop a technology capable of modernizing the depot handling of fasteners. The ultimate objectives of this effort were to:

a. Provide a practical means of performing a limited technical inspection (LTI) of fasteners as they are received from suppliers.

b. Identify potential non-conformities in fasteners, including: material composition, plating, heat treatment, thread profile and geometry.

c. Enable the DLA to purchase fasteners in economical, bulk quantities directly from the manufacturer.

d. Improve inventory management of critical parts.

e. Reduce parts proliferation. Part profiles could be generated from received material and matched against existing stock numbers to avoid needless duplication.

f. Identify material returned to depot storage to avoid mixed stock numbers.

The original proposed system is illustrated schematically in Figure 1, where the flow of parts and information are shown. The original concept for the technology development was limited to fasteners. After some investigation in this effort, it became clear that the proposed technology development could apply to many other commodities. In order to maintain the scope of the contract, the work was directed at a prototype effort that was confined to threaded fasteners with heads.

The investigation centered on specifying a technology development program (embodied in Phase II of the research) would provide a means of modernizing the handling of highly critical components of military hardware. This manufacturing and logistics improvement program is directed at enhancing the fastener handling and distribution process, generating both a cost and strategic advantage for the Department of Defense.

PRDA 90-01 called for a two phase effort to address the manufacturing problem under investigation. In Phase I, the problem is identified, the solution methodology is proposed and the benefits to be derived from the research are quantified. Phase II work consists of applying the solution methodology developed in Phase I. This report details the investigation into the problems and the identification of a solution methodology.

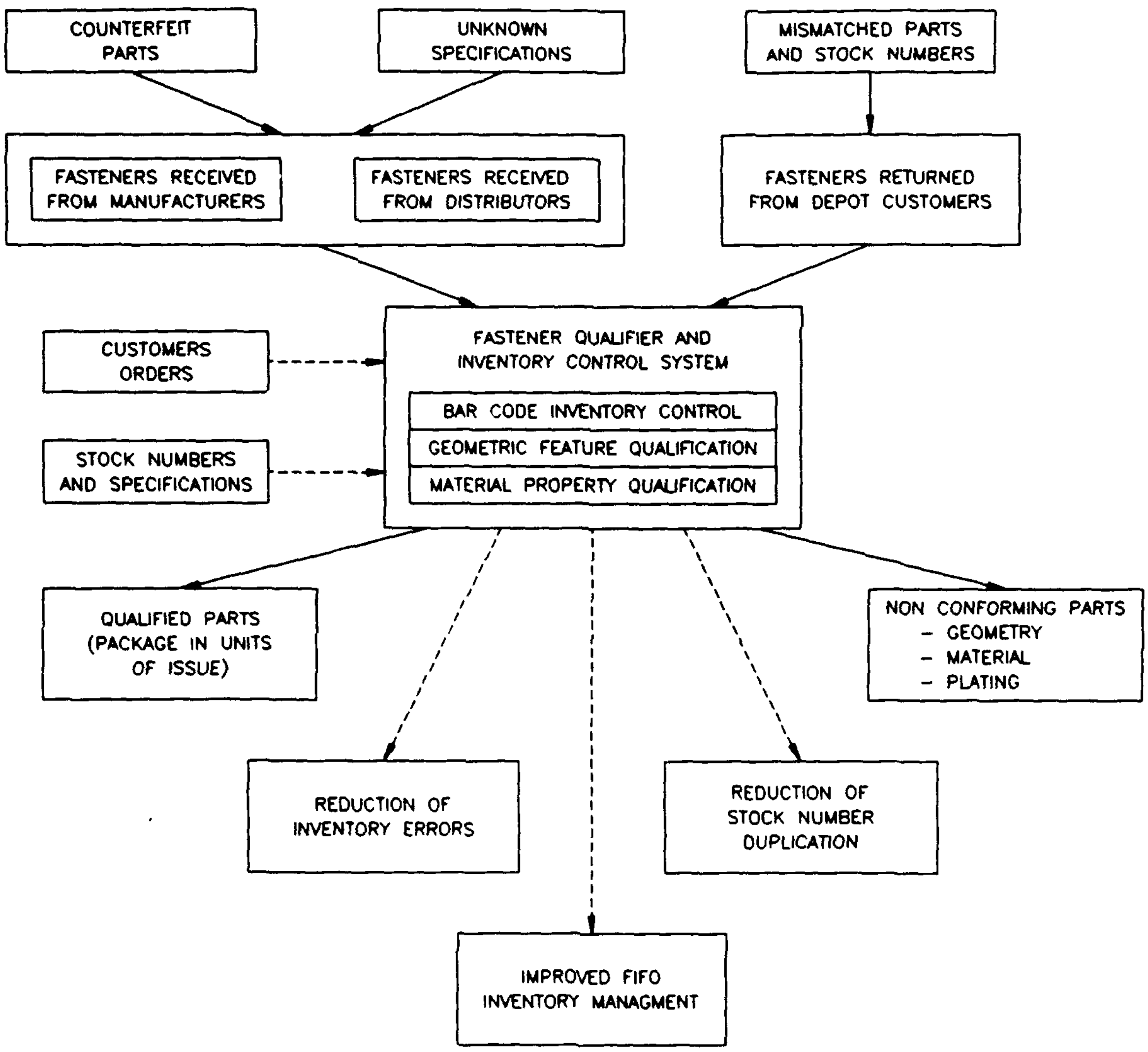

Figure 1 Original Concept for a Fastener Quality Management System

2. Investigation Plan

The development of a fastener inventory control system was analyzed from several different perspectives. The procurer, manufacturer, distributor, testing laboratories and the depot were considered in order to understand the requirements of a practical fastener inventory control technology. In addition, various technologies were investigated that could be integrated into a system capable of providing the necessary functions.

2.1 Areas Investigated

Five major areas of the fastener supply infrastructure were examined as part of this investigation: procurement, manufacturing, distribution, testing laboratories and depots.

Personnel in the procurement area were considered in the study of this problem. The procurement system, the Defense Industrial Supply Center (DISC), is the organization that is ultimately responsible for the purchase of these commodities and countless other industrial products. Specifications, quantities, distribution and storage logistics are all key elements in identifying the important issues in the fastener problem.

Fastener manufacturers were consulted in order to identify the constraints and barriers facing the companies that domestically produce fasteners for use in military hardware. Manufacturing processes, internal quality control and testing, handling, storage and lot control were examined. Since a major portion of the fasteners that are procured for use in military hardware are purchased from distributors, this sector of the fastener manufacturing community was examined. The distributor plays a major role in the supply of fasteners for military application. Since DISC purchases such a wide variety of fasteners in limited quantities, the economies of scale suggest that purchases be made from distributors.

Testing Laboratories play a vital role in determining if the quality characteristics of a fastener are within specifications. Currently, this is the only audit system available for assessing the geometric and metallurgical characteristics of fasteners. This study examined test procedures, certification techniques and data collection methods that are used in modern laboratories.

This study also included examination of depot facilities for determining the functional requirements of a fastener identification/validation system. Based on direction and guidance from DISC personnel, specific depot site visits were arranged to assess the role of a limited technical inspection/inventory control system. Functional requirements, practical limitations and system integration issues were characterized based on the necessary elements of the fastener procurement and handling operation. A strong emphasis was made in human factors and existing inventory control strategies in order to identify a practical system for these environments.

As the investigation progressed, the emphasis was increasingly directed at a customer for the technology development within the depot system. As a result, most of the investigation centered on the procurement and depot functions.

2.2 Technologies Investigated

Five major technologies associated with fastener validation and identification were examined as part of this investigation: inventory control, geometric qualification, material qualification, plating and coating qualification.

This system requires identification of appropriate inventory control system technologies. The system considered elements of inventory storage and retrieval methods, database design and computer implementation.

Many of the critical performance requirements of a fastener are related to geometry. The fastener identification/validation system must be capable of extracting geometric information from parts as they are received and processed. Some of the critical areas of the geometry that must be considered are: diameters, thread profile, length and head shape.

Material qualification figures most prominently in the requirements for fastener qualification. Most methods for qualifying fasteners call for time-consuming and potentially destructive testing of sample parts. In the design philosophy of the proposed system, a limited technical inspection of part received at the depot should offer a fast, non-destructive means of evaluating the material properties of parts. Magnetic/inductive sensing and eddy current techniques can provide this capability depending on the application.

A practical fastener identification/validation system must consider plating and coating as part of the quality characterization of the part. A sensor technology investigation was conducted for these functional requirements.

2.3 Literature Survey

This investigation included an extensive literature survey of government documents, published material and commercial documents. This data coupled with the site visits to various facilities, developed the framework for the solution identification phase of the project. The literature survey considered the background of the problem that motivated the investigation, the new legislation related to fasteners and relevant accreditation programs.

2.3.1 Background on Problems with Fasteners in the Department of Defense

2.3.1.1 Non-Conforming Parts in the Defense Inventory

The original motivation for this research stems from widely publicized problems with non-conforming fasteners purchased for use in the armed services. Most of these problems were related to a high strength designation part, the SAE Grade 8.0. The Grade 8.0 fastener is made from high strength steel and processed under special conditions to give it superior mechanical properties. The Department of Defense has over 400 weapons and other equipment using SAE Grade 8.0 fasteners [105]. The Defense Industrial Supply Center (DISC) supplies Grade 8.0 fasteners to the armed services under some 900 national stock numbers (NSNs). DISC purchases roughly 100 million grade 8.0 fasteners in a 2 year period. In the late 1980s, tests on samples from various lots in an inventory roughly equal to 2 years supply indicated a non-conformance rate to Grade 8.0 specifications in excess of thirty percent [104]. There could be a significant cost advantage for an unscrupulous contractor substituting another type of fastener for a Grade 8.0. For example, there is a 30% cost advantage of representing a Grade 8.2 as a Grade 8.0.

Problems with bolt failures in military vehicles suggested a potential problem with military readiness. As a result, the DLA spent $5 million identifying nearly 30 million nonconforming fasteners from 90 million fasteners in frozen inventory [104, 106].

2.3.1.2 Problems in Procurement

Depots receive lists from DISC via DESCOM (Depot Systems Command) of nonconforming bolts based on NSNs. DISC prepared 13 lists but DESCOM sent only 11 to the Depots. Furthermore, debarment by DISC has been ineffective in removing sellers of substandard fasteners from approved contractors list. Problems with debarment is not the only reason that suppliers of substandard materials are able to continue to sell to the government. The Small Business Administration (SBA) can and does intervene to protect petitioning small businesses from the sanctions which DISC and other government purchasing offices would otherwise impose.

There were 440 contracts due at the time DISC instituted its receipt testing program. When the contractors discovered their supplies would be tested, 83 of 440 contracts (19%), were unilaterally canceled [104]. Presumably, this was due to intentional substitution of non-conforming parts by those contractors.

2.3.2 Background on the Fastener Quality Act

The problems with non-conforming fasteners sold to the government and commercial industry ultimately resulted in new legislation to define the conditions for the sale of fasteners in commerce. In November of 1990, President Bush signed into law the Fastener Quality Act (PL 101-103). The Fastener Quality Act was based on H.R. 3000, a bill to improve the testing and traceability of bolts and other fasteners used in critical applications such as aircraft, military equipment of all kinds, trucks, buildings and nuclear power plants [105-107].

The purpose of the bill is to establish procedures to provide customers who buy certain high-strength bolts, screws, and other fasteners used in critical applications with greater assurance that the fasteners they purchase meet stated specifications and do not include substandard or counterfeit items.

The Fastener Quality Act has twin goals - prevention and traceability: each lot of high strength bolts is tested by an accredited laboratory, test reports must be available to customers. The law is designed to ensure the quality of product sold by distributors. Requiring testing at the manufacturing stage helps little, if unethical distributors are able to substitute cheap bogus parts during the sales stage.

2.3.2.1 Substandard Fasteners Sold in Commerce

The American economy uses 200 billion fasteners annually, over seven billion are large screws and bolts. Some 1.5 billion are high strength, heat treated fasteners corresponding to the Grade 8.0 standard of the SAE. Counterfeit, substandard, and mismarked fasteners have been sold to private sector firms all over the country. These firms erect buildings, manufacture equipment, mine ore, and build and rebuild a variety of vehicles, reducing combat readiness, endangering safety of federal projects and threatening the health and safety of Americans [104].

The Aerospace Industries Association instituted a testing program on Class III aerospace fasteners in 1987 where 38.6% were found nonconforming. The National Transportation Safety Board reports that sixty-one aviation accidents have involved fastener failures over the three year period, 1984-1987.

FMC Corporation uses 1 million grade 8.0 fasteners each year on the Bradley Fighting Vehicles, after inspection of their inventory, FMC disposed of $700,000 worth of bolts. General Dynamics, who produces the M-1 tank, discovers during the last quarter of 1986 approximately 13,000 nonconforming grade 8 bolts. In other examples, the Nuclear Regulatory Commission has been aware of serious fastener problems in nuclear power plants since 1982. The Houston Metropolitan Transit Authority was advised that 92% of its repair fastener inventory was counterfeit.

2.3.2.2 Position of Fastener Industry

Fastener industry is a $4 billion business in the United States. The Industrial Fasteners Institute, representing about 75% of the fastener manufacturing capacity in USA, supported H.R. 3000. The position of the IFI is that the problems with non-conformances are due to overseas suppliers [106]. They believe the Fastener Quality Act would help American industry. According to IFI the common fastener problems are:

- Material Substitution
- False Certifications

- Inconsistent Heat Treatments
- Absence of Stress Relief
- Wrong Plating Materials
- Meaningless Performance Markings that have no foundation in specifications and standards
- Absence of manufacturer's symbols and/or the use of symbols that are not traceable.
- Improper Thread Engagement
- Mismarked Performance Headmarks

However, some small manufacturers believe that the bill would put them out of business because unscrupulous manufacturers would still evade the bill [75]. In addition, there are 5000 fastener distributors in the United States and between 100 to 200 foreign manufacturers are supplying the US market. Distributors claim they accepted fasteners in good faith and have limited financial assets -- when confronted with charges of deliberate non-conforming parts, they go out of business

Not surprisingly, the American Association of Fastener Importers (AAFI) was opposed to H.R. 3000 [106]. The AAFI represents 16 of the largest importers of general use fasteners in the United States. The AAFI position on H.R. 3000 was that the legislation would have an inflationary impact on their customers and cause product shortages due to the delays introduced by the inspection procedures. Furthermore, they saw it as a restraint of trade.

2.3.3 Requirements of the PL 101-103

This legislation is designed to ensure that a supply of quality fasteners exists for use in critical applications. It requires final testing of sample fasteners by an accredited laboratory for conformance to standards, specifications, and grade identification markings, before the lot from which the sample is drawn can be sold. The act also requires certificates of conformance to document the test results, traceability through a registered manufactures's mark on the fastener, and a lot number identification on the shipping container. Civil and criminal penalties will encourage compliance [69].

The law provides a specific definition of a fastener:

a. *A screw, nut, bolt or stud with internal or external threads or load indicating washer of metal, 1/4" or (M5) and larger and through hardened.*

b. *A screw, nut, bolt or stud bearing a grade identification marking required by standard or specification.*

c. *A washer when it is subject to a standard or specification applicable to the product included with the definition of (b).*

d. *Items added from time to time by the Secretary of Commerce.*
The only exception is ASTM A307 Grade A bolts and studs which are specifically excluded from the provisions of this act.

e. *It should be noted that (b) includes stainless and nonferrous fasteners manufactured in accordance with ASTM standards F16 (F467, F467M, F468M, F593, F594, F738M, and F836M.)*

The law also provides a specific definition of a lot:

Lot is a quantity of fasteners of one part number fabricated by the same production process from the same coil or heat number of metal as provided by the metal manufacturer and submitted for inspection and testing at one time.

The terms "through hardening" and "alter" are also very specifically defined:

Through Hardening: *Heating above the transformation temperature followed by quenching and tempering.*

Alter: *Through-hardening, electroplating of fasteners having a minimum tensile strength of 150 ksi or machining. Section 3 of the Law list other definitions.*

According to the law, no fastener can be sold in US unless it:

- Conforms to standards and specifications to which the manufacturer represents it has been manufactured.
- Has been inspected, tested, and certified by lot number. It is unlawful for a manufacturer of domestically produced fasteners to sell containers of fasteners unless accompanied by written notification that they were tested and certified by an accredited laboratory. The Act provides an option for importers and private label distributors to assume the responsibility for inspection and testing. Certification of the results must be provided in writing and the foreign manufacturer must disclose the standards and specifications to which the lot was manufactured.
- Inspection and testing will establish that the lot conforms to the standards and specifications to which it reportedly has been manufactured.

The law will also require:

- Containers of fasteners sold wholesale to be marked conspicuously with lot numbers. Lots may not be commingled in the same container at the wholesale level. This will help to insure traceability. Requirements limiting commingling of fasteners do not apply to sales of fasteners by Original Equipment Manufacturers (OEM) to their authorized dealers for use in assembly or servicing those products manufactured by OEM.
- The person who perform fastener alteration either must have the altered fastener tested and certified to establish the new characteristics, or must provide a written statement disclosing the alteration.
- Laboratories, manufacturers, importers, and private label distributors must retain records of fastener testing and certification for 7 years, to insure traceability.

Certification for 50 pieces or smaller lots may be forwarded after shipment. Small lot fasteners may be sold, provided that inspection, testing and certification is carried out and written notice of the results are sent to the end user, as soon as practicable after the sale. The purpose of this exception is to allow for emergency orders. Retail certification is possible only if requested in advance. Test sample size and selection are in accordance with applicable standards and/or specifications.

Laboratory reports shall include:

- Manufacturer's name.
- Part description.
- Lot number.
- Notation of grade or property class mark and manufacturer's or private label distributor's insignia present on samples.
- Reference those standards and specifications disclosed by manufacturer for the given lot.
- Statement of conformance or lack of conformance.

Laboratory certificates shall bear the original signature of a responsible employee or officer as established by the Secretary of Commerce. An accredited laboratory may be owned by the manufacturer or may be an unaffiliated laboratory. Conditions will be defined which will allow accreditation of foreign laboratories.

Some specific details about the accreditation of laboratories are as follows:

- No accreditation provided shall be effective for a period greater than 3 years.
- Secretary of Commerce may require any private entity or laboratory to provide all of its records.
- Private sector standards that may be reviewed for adoption in lab accreditation: ASTM E994, ISO/IEC Guides 2, 25, 38, 43, 45, 49, 54 and 55.
- Laboratory Accreditation may be by private entities if the accreditation process meets the criteria established by the program. NIST does not endorse accrediting organizations.

There are two laboratory accreditation programs in the private sector that have been brought to the attention of the Committee. One is an existing program operated by the American Association for Laboratory Accreditation (A2LA). The other program is being planned by the American Society of Mechanical Engineers (ASME). These are the types of programs the Committee has in mind when directing NIST to rely on the private sector.

Operation of the laboratory accreditation program by the NIST will be on a cost-reimbursable basis, fees will be charged to the labs being accredited. NIST may hire contractors (use private sector experience). The effective period of accreditation is limited to three years. At the time of this writing, the recommendations on features of the implementation of the law from the Secretary of Commerce have not been finalized.

2.3.4 Fastener Standards

Since the Fastener Quality Act focusses on specific fastener standards, the literature survey included a review of the relevant organizational standards.

2.3.4.1 SAE Standards

The SAE standards cover the chemical, metallurgical and mechanical requirements for metric and non-metric fasteners used in automotive and related industries. In addition these specifications establish procedures for conducting standard quality tests to determine the mechanical properties of externally and internally threaded fasteners. Recommended headmarkings to distinguish grades are also standardized [84 - 92]. Figure 2 shows the various SAE standard fasteners types and their characteristics.

			Full Size Bolts, Screws, Studs, Sems		Machine Test Specimens of Bolts, Screws, and Studs				Surface Hardness	Core Hardness		
										Rockwell		
Grade Designation	Products	Nominal Size Dia, in	Proof Load (Stress), psi	Tensile Strength (Stress) Min, psi	Yield[a] Strength (Stress) Min, psi	Tensile Strength (Stress) Min, psi	Elongation[f] Min, %	Reduction of Area Min, %	Rockwell 30N Max	Min	Max	Grade Identification Marking[i]
1	Bolts, Screws, Studs	1/4 thru 1-1/2	33 000[a]	60 000	36 000[b]	60 000	18	35	—	B70	B100	None
2	Bolts, Screws, Studs	1/4 thru 3/4[c]	55 000[a]	74 000	57 000	74 000	18	35	—	B80	B100	
		Over 3/4 to 1-1/2	33 000	60 000	36 000[b]	60 000	18	35	—	B70	B100	None
4	Studs	1/4 thru 1-1/2	65 000	115 000	100 000	115 000	10	35	—	C22	C32	None
5	Bolts, Screws, Studs	1/4 thru 1	85 000	120 000	92 000	120 000	14	35	54	C25	C34	
		Over 1 to 1-1/2	74 000	105 000	81 000	105 000	14	35	50	C19	C30	
5.1[d]	Sems,[h] Bolts, Screws	No. 6 thru 5/8	85 000	120 000	—	—	—	—	59.5[g]	C25	C40[g]	
		No. 6 thru 1/2										
5.2	Bolts Screws	1/4 thru 1	85 000	120 000	92 000	120 000	14	35	56	C26	C36	
7[e]	Bolts Screws	1/4 thru 1-1/2	105 000	133 000	115 000	133 000	12	35	54	C28	C34	
8	Bolts, Screws, Studs	1/4 thru 1-1/2	120 000	150 000	130 000	150 000	12	35	58.6	C33	C39	
8.1	Studs	1/4 thru 1-1/2	120 000	150 000	130 000	150 000	10	35	—	C32	C38	None
8.2	Bolts Screws	1/4 thru 1	120 000	150 000	130 000	150 000	10	35	58.6	C33	C39	

Figure 2 SAE Standards

2.3.4.2 ASTM Standards

These specifications cover chemical and mechanical requirements for carbon and alloy steel fasteners for general structural and mechanical uses. Furthermore the standards cover metric and non-metric fasteners, as well as nonferrous fasteners suited in general engineering applications. Standard methods for conducting tests to determine the mechanical properties of externally and internally threaded fasteners, washers and rivets are proposed [14 - 24].

2.3.4.3 Headmarking

No real standard exists for headmarkings at this time. The Fastener Quality Act calls for a standardization effort where headmarkings are registered as a trademark. Source marking promotes quality assurance since the fastener supplier knows that by affixing its mark to the product, it will be held accountable for any such failure of lack of conformity. Markings on bolts and screws are usually located on the top of their heads; those on studs on their ends; and on nuts on their top face [68].

ASME Committee B18 Subcommittee 25 is preparing a draft standard of criteria for use by companies to register their symbols with the ASME. Some examples of manufacturer's headmarkings are shown in *Figure 3*.

2.3.5 Accreditation Programs for the Improvement of Fastener Quality

2.3.5.1 Laboratory Accreditation Programs

The ASTM E994-84 guide identifies important features of systems which accredit testing laboratories, inspection bodies, or other organizations involved in testing, measuring, inspecting, and calibrating activities [13].

The Fastener Quality Act calls for the National Institute for Standards and Technology (NIST) to deliver recommendations to the Secretary of Commerce on procedures for laboratory accreditation [69]. The NIST also operates NVLAP (National Voluntary Laboratory Accreditation Program). The American Association for Laboratory Accreditation (A2LA), a private organization dedicated to the formal recognition of competent laboratories believes that NIST fails to recognize it because A2LA is a direct competitor of the NVLAP [106].

2.3.5.2 Fastener Quality Assurance Program

The Fastener Accreditation Program (FAP) was developed by the American Society of Mechanical Engineers (ASME) to stop the flow of counterfeit and substandard fasteners into the United States and restore confidence in US manufacturing [12].

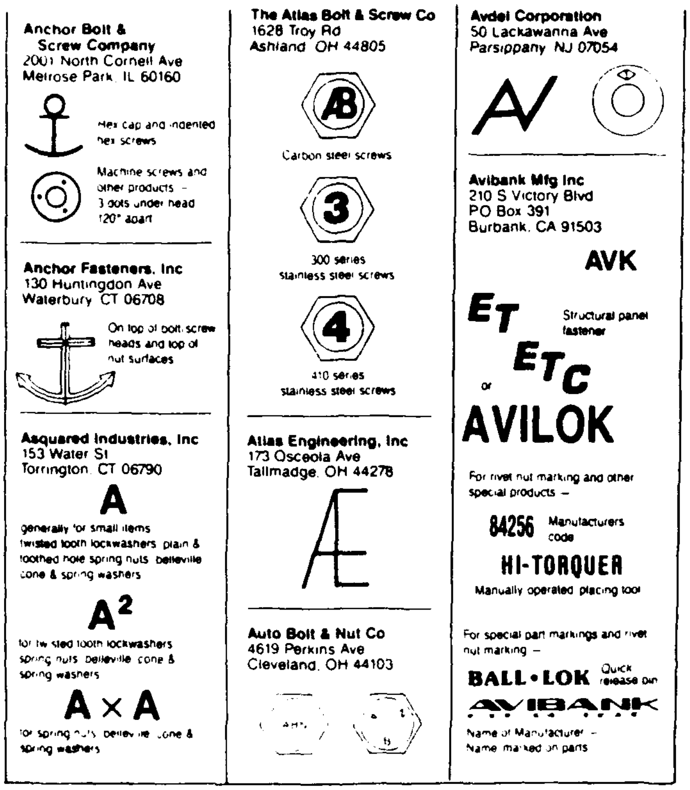

Figure 3 Fastener Headmarkings

To review the applicants, ASME has established survey teams to evaluate their program and submit a written report to ASME. The ASME will audit the approved programs on a random programmed basis over the three year life of the certificate. The survey teams consists of ASME consultants experienced in the field of quality assurance. There are two types of surveys: Fastener Manufacturer (or Alteration Distributor) *FM* and Fastener Distributor (Non-Alteration) *FD*.

The ASME will issue a certificate to a manufacturer or distributor who has a program of quality assurance and quality control conforming to the ASME standard. The standard sets forth the requirements for engineering drawings, tooling, production planning and lot control, procurement, raw material and traceability, personnel training, and other elements of quality control. FAP provides the user with a reliable and cost-effective means to rate a supplier's quality assurance and quality control programs. Accreditation also benefits the supplier who wants to let customers know that it has successfully demonstrated a program of quality control in the manufacture or distribution of fasteners.

The organization desiring fastener accreditation applies to the ASME presenting an applicant's quality assurance manual. Written quality control material must focus on personnel, operational structure, equipment and other evidence of a company's capability to produce or distribute a high, quality, durable and safe fastener product. ASME will perform an "on site review to assure conformance to written quality plan. Suppliers who meet ASME standards are issued a certificate of accreditation, which generally covers a 3 year period. During this term, ASME monitors the organization to assure continued adherence to the accreditation program.

2.4 Investigative Site Visits

Six investigative site visits were made based on the preliminary plans outlined in the original proposal and additional guidance from the contracting personnel. These visits permitted first hand knowledge of the operations of depots, supply centers and manufacturing facilities. These visits were instrumental in preparation of the Phase II proposal. The following is a chronological log of the investigative site visits that were conducted.

1. Visit to Defense Industrial Supply Center (DISC) and Defense Distribution Region East (DDRE)

   Period: 1 August 1991 - 2 August 1991

   Purpose: The trip allowed in depth discussion with a wide range of DISC personnel involved in the procurement, standardization and material management aspects of fasteners. Many questions related to the problem formulation were answered. Preliminary ideas for Phase II work were identified. The trip also afforded an opportunity to see actual depot operations at DDRE in the Mechanicsburg and New Cumberland facilities. Many aspects of modernized material management were seen first hand.

2. Visit to Defense Distribution Region East (DDRE)

   Period: 2 Sept 1991 - 2 Sept 1991

   Purpose: The trip afforded an opportunity to see actual receiving inspection and identification operations at the New Cumberland and Mechanicsburg facilities. The problems of performing complex product inspection operations on numerous components were seen first hand.

3. Visit to Fabristeel

Period: 9 Sept 1991

Purpose: This visit to a fastener manufacturer in the Detroit area took place as part of a post-award meeting at the University of Detroit Mercy. Representatives from the DLA/DESC (CO), DLA-PRM (COTR) and ONRRR (ACO) were in attendance along with the principal investigator. The group was able to see all aspects of the manufacture of pierce-nut products and talk with the company management about the implications of the Fastener Quality Act and research on this contract.

4. Briefing at DLA-PRM (Manufacturing Engineering Branch)

Period: 1 November 1991

Purpose: The briefing allowed an opportunity to review the results of the investigation to date, plan additional site visits, present the proposed Phase II investigation strategy and plan the final contract briefing. The meeting included Donald F. O'Brien, Chief, DLA Manufacturing Engineering Branch.

5. Site Visit to Defense Distribution Region Central (DDRC)

Period: 18 November 1991

Purpose: The trip afforded an opportunity to see actual receiving inspection and identification operations at the Memphis Distribution Site (Defense Depot Region Central). The problems of performing complex product inspection operations on numerous components were seen first hand. The trip also provided perspective on the diversity of facilities and equipment in the Depot system. The Memphis site has not received the high level of investment in automation and facilities that was witnessed in other site visits. The efficiency of production, facilities maintenance and integration of technology was not at the same level as newer facilities such as DDRE (Eastern Distribution Center - New Cumberland and Integrated Materials Center - Mechanicsburg). It is critical to visit multiple sites to fully understand the scope of the problem as described in the original technical proposal.

6. Hardware Demonstration at Defense Distribution Region East (DDRE)

Period: 18 November 1991

Purpose: The trip afforded an opportunity to demonstrate some of the hardware recommended for the Phase II proposal activity. Two pieces of the proposed system were demonstrated independently to Distribution and Quality directorate personnel. Thomas Leone, CMI International, was present to demonstrate his company's XRX system for plating identification and thickness measurement. Considerable interest on the part of DDRE personnel was evident. The XRX system appears to be able to provide capabilities that are not currently available at the depot. A Magnetic Analysis Corporation (MAC) Verimac III eddy current comparator was also demonstrated to identify various metallurgical conditions corresponding to fastener grades.

2.5 Technology Survey

The technologies that were investigated in this research are summarized in Section 2.1. The following describes the important features of the various technologies that are relevant to this investigation.

2.5.1 Inventory Control

All of the replacement parts for weapon systems, uniforms and commodity items, personal gear and medicines are called secondary items. In order to increase force readiness, secondary item inventory has grown from $43.4 billion in 1980 to $90 billion in 1986. In the same period the demands for secondary items remained relatively constant. Demands increased 11% from 1980 to 1984. By 1986, the number of demands returned to the 1980 level. The DLA issues $100 billion in material to its worldwide customers annually, supplying them 7 days a week the 365 days of the year. The value of supply inventory is ten times bigger than the five top Fortune 500 companies combined [108,111,112].

The DoD supply system has 4.5 million different items. Inventories are valued at $90 billion and items stored at thousands of locations worldwide. There are 30 million customer demand transactions and $40 billion of material issued annually. A typical distribution center has 1 million individual storage locations.

By necessity, inventory control programs are designed to be selective. Efforts are concentrated on known problem items and those which are most important. The DLA inventory control program is composed of 5 program elements:

a. Location Audits
No material is physically counted, but the process rapidly identifies problem areas that require correction and areas where physical inventories (counts) may be needed.

b. Physical Inventories
Counting the material in the storage location and comparing the count to the accountable record.

c. Research
The process of analyzing variances that are uncovered by the physical inventory program element. Research seeks to prevent erroneous adjustments and to identify the causes for actual variances in order to prevent their recurrence.

d. Quality Control
Identification of human, procedural or system errors that adversely affect the asset balance accuracy.

e. Performance Measurement
The Inventory Control Effectiveness (ICE) reporting system provides statistics and accuracy rates on materiel denials, receipt processing, location audits and inventory accuracy.

The GAO reports that a statistical sample of 330 items showed that the inventory records for about 56% of the items were inaccurate and that dollar value variances as high as 40% and unit variances as high as 36%. In 1982, the subject of inventory record accuracy was included as a high interest item of the Defense Council on Integrity and Management Improvement (DCIMI).

This high-level emphasis on inventory control and accuracy has resulted in the following :

- Reissuance of DoD Instruction 4140.35, which prescribes the DoD inventory control policies.
- Policy Enhancements:
    - Expand DoD physical inventory control policy to cover all supply system inventories.
    - Apply inventory control resources toward force readiness and integrity of accountable records.
- Responsibility Enhancements:
    - Require the DoD Inspector General to conduct periodic evaluations of the entire inventory control program.
    - Heads of DoD components must provide management priority and resources for the execution of physical inventory control functions.
    - Materiel Accountability and Inventory accuracy must be mandatory.
- Procedures and Technology Enhancements:
    - Require quality control, research and investigations.
    - Use LOGMARS (Logistics Applications of Automated Marking and Reading

Symbols), bar codes for control of materiel receipt, storage and issue.

- Apply new communications and information processing technology to improve the ability of the DoD systems to communicate.
- Implement MILSTRAP (Military Standard Transaction and Accounting Procedures).

2.5.2 Geometric Qualification

Many of the critical performance requirements of a fastener are related to geometry. The fastener quality management system must be capable of extracting geometric information from parts as they are returned from depot customers and returned to stock for purposes of assuring inventory integrity. Some of the critical areas of the geometry that must be considered are: diameters, thread profile, length and head shape.

Machine Vision products can perform non-contact measurements such as length, width, contour and area. In addition they can examine a part and compare it to stored information, based on this comparison, good-part/bad-part decisions can be made. For all these reasons, machine vision products from different U.S. vendors were investigated, a summary follows:

a. Allen-Bradley

The Allen-Bradley vision family provides an adaptable set of vision tools to meet a wide range of applications [1-10]. Allen-Bradley machine vision products can perform non-contact measurements such as length, width and contour area.

The Configurable Vision Input Module (CVIM) is designed for sophisticated process inspection and control applications. All set-up and configuration is done with a light pen, monitor, and pop-up menus. The CVIM module (Figure 4) is able to inspect up to 1800 parts per minute and can operate one or two high-resolution cameras for more accurate inspections. The CVIM module has an extensive set of vision analysis tools to automate the inspection, gaging, measurement and part identification.

The Vision Input Module (VIM) shown in Figure 5 is a low cost module able to inspect up to 1800 parts per minute and can be used as stand alone, or can be connected to an Allen-Bradley PLC programmable controller hosting a complementary line of I/O modules. The VIM is programmed by user friendly menus. In addition, images from separate cameras can be combined using an Allen-Bradley Camera Mux Module, that switches or combines the images from two video cameras into a single image.

The Line Scan Camera (Figure 6) provides high resolution coupled with high speed performance at low cost. The camera can operate as a stand alone unit or be controlled via RS-232 port with an Allen-Bradley PLC programmable controller or a host computer. The camera has built-in diagnostics, help screens and a document page for instant status reports, and can be easily configured with a light pen and monitor. The Line Scan Camera has 17

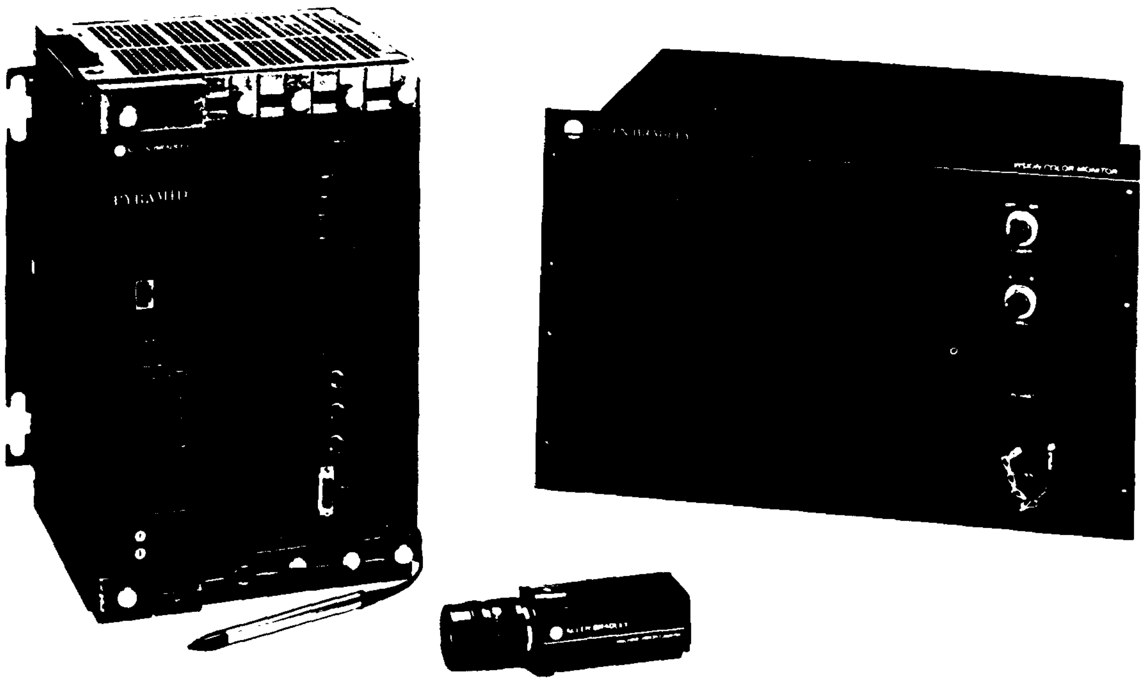

Figure 4 CVIM

measurement functions using 4 line gages to count and measure features.

b. CIDTEC

CIDTEC offers a family of Charge Injection Device (CID) cameras [26]. CID design objectives focus on achieving complete, accurate, and distortion-free image data acquisition for computer processing with fast, flexible timing and function control. CID technology has been embraced in test and measurement, scientific instrumentation, tracking and guidance, and high-speed machine vision applications. Useful attributes include: contiguous pixel structures for complete, accurate image detail; inherent anti-blooming performance for distortion-free output; UV response to 185 nanometers and near-IR response without blooming or fringing for extended spectral range and asynchronous timing for full-frame capture of short-duration events.

CIDTEC offers a wide range of solid state monochrome video cameras (Figure 7) as well as custom sensor and camera design support. All cameras can be connected in DATACUBE, DATA TRANSLATION, IMAGING TECHNOLOGIES and POYNTING PRODUCTS frame grabber boards for image processing on various computer systems.

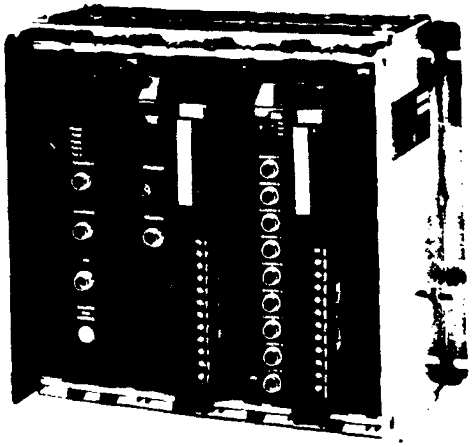

Figure 5 VIM

c. Dickerson Vision Technologies

Dickerson Vision Technologies (DVT) provides an integrated vision camera/processing system that contains an integrated illumination, optics, a CCD array detector, computer and software in a single packaged device. This unit, the Stinger 70 IVS, provides a grey scale vision system at a low hardware cost [31]. The unit contains the same functionality of a conventional vision system (camera, frame grabber, computer and illumination) in a single highly integrated package the size of a book as shown in Figure 8. The Stinger 70 IVS uses a Motorola 68000 CPU and specialized electronics to achieve image definition of 32,000 pixels with a maximum full frame rate of 100 Hz.

Customers by the basic camera/computer unit and specialized software suited to each application. DVT offers software packages for a variety of applications including landmark tracking, parts locating, bar code reading, feature analysis, navigation and label alignment. This technology was developed by the Material Handling Research Center, MHRC, of the Georgia Institute of Technology.

Figure 6 Line Scan Camera

d. Eastman Technology

VIDEK a division of Eastman Technology designs an advanced line of vision inspection systems which are used as process control tools for different manufacturing applications [32-40]. VIDEK Systems Division's product offering consists of the following standard vision inspection systems:

VIDEK RM 500 is tailored to provide real-time inspection for production lines with less demanding performance requirements. It operates at production line speeds of up to 500 parts/minute, while providing 100% real-time inspection. It is available in a choice of NEMA enclosures. VIDEK RM 1000 is the system for very demanding production line performance requirements. It will operate at speeds of up to 1000 parts per minute, providing 100% real-time inspection. It also comes in a choice of enclosures.

VIDEK PAC 500 combines all of the standard features of the VIDEK RM 500/1000 in a modular design, consisting of small, convenient enclosures that easily adapt to most production lines. It operates at speeds of up to 500 parts per minute at 100% real-time inspection. VIDEK PAC 1000 is engineered for the most demanding applications. It operates at speeds of up to 1000 parts per minute while maintaining the same compact, modular design of the VIDEK PAC 500 Vision Inspection System.

All of the VIDEK Vision Inspection Systems described above allow to set the accept/reject

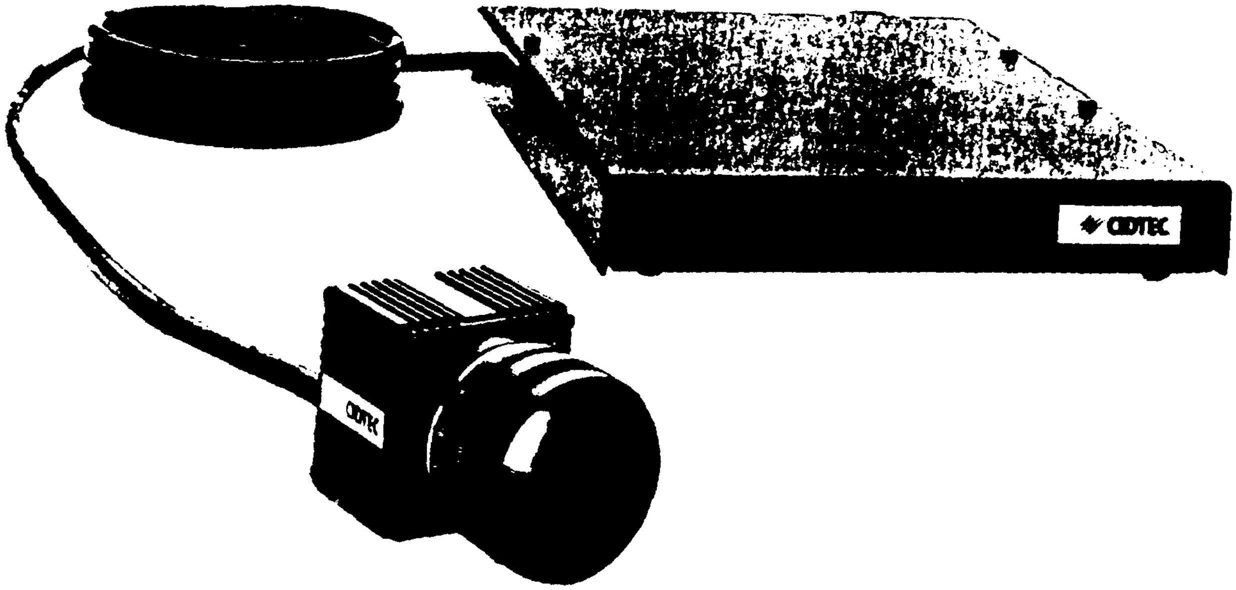

Figure 7 CIDTEC Camera

limits for over 100 measurements on the product. These systems process a full 256 light intensity levels, or shades of gray. They have an user-friendly series of on-screen prompts and a full complement of I/O lines and communications interfaces for easy linking with other factory control devices.

e. Hitachi

Hitachi offers a line of cameras, video monitors, and high resolution disk recorders [47-55]. The Hitachi KP-140 (Figure 9) series is a high sensitivity black and white camera employing an inter-line transfer type charge coupled device (CCD). The compact and lightweight camera KP-140 series has features which include little picture distortion, low lag and long life. The KP-140 series is most suitable for visual sensors, image processing systems, instrumentation and other monitoring applications. The Hitachi KP-C200 series single chip solid-state color TV cameras using a high sensitivity and high density imaging device are intended to be used in industrial fields. The KP-C200 series feature high sensitivity and high fidelity picture, and incorporate various functions including setup control, color bar signal generator and sensitivity selection. These functions, coupled with compact and light-weight camera heads, render the KP-C200 series cameras suitable for medical and industrial applications.

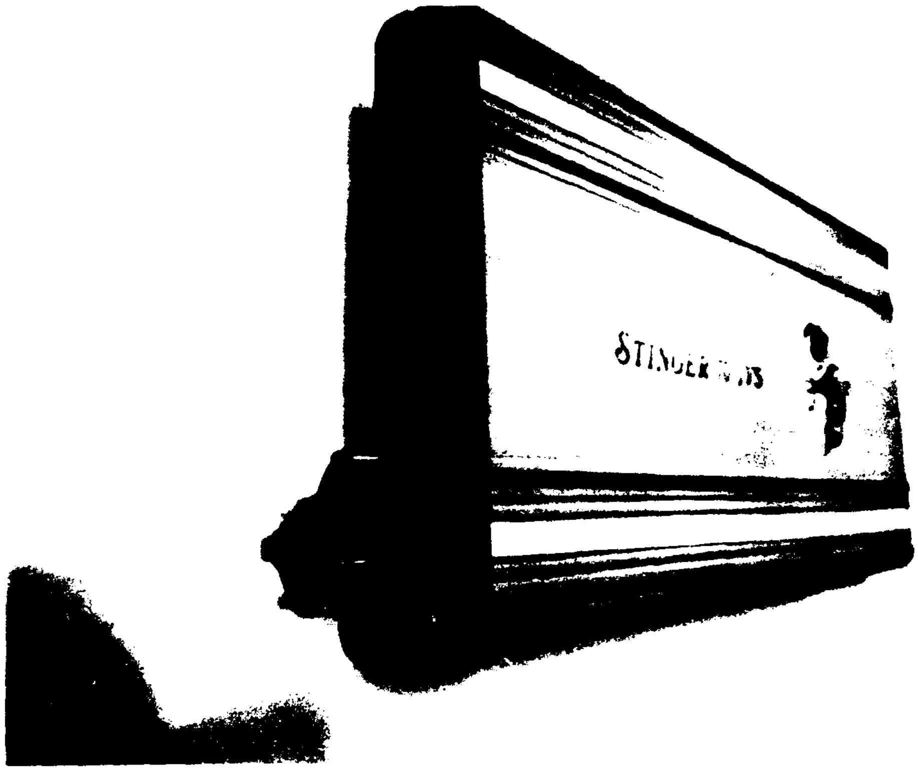

Figure 8 DVT Stinger 70 IVS

Hitachi offers a 9, 12, and 17 inches monochrome video monitors with high resolution picture due to the use of a wide bandwidth video amplifier and dynamic focusing. The white suppress circuit allows high quality picture and the built-in underscan select function produces minimax picture degradation.

The Hitachi high resolution color disk recorder is a high resolution freeze-picture filing equipment which records video signals having high resolution of 1049 scanning lines in a hard disk or an optical write-once disk after digitizing the signals by means of a high speed AD converter. The HF-3100 is capable of recording, playing back and erasing 30 sheets of freeze-pictures in the built-in hard disk. The HF-3200 is provided with a 5.25" optical write-once disk in addition to the hard disk, and can record and play back 140 freeze pictures in both sides of the optical disk.

f. I2S

I2Ss a major manufacturer of solid-state CCD cameras and high performance subsystems for industrial, medical, military, and security applications [56].

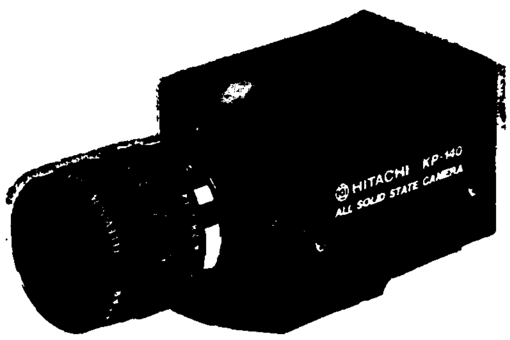

Figure 9 KP-140 Series Cameras

The NUMEVISION subsystem has been specially designed for automated inspection and assembly, and consists of a high-resolution line scan camera interfaced to one or more dedicated controller boards which are PC-compatible. A linear array sensor within the camera scans the field of view, and the camera digitizes the signal and outputs it to the controller board within a PC workstation. This configuration has been successfully adapted to a variety of industrial applications such as automatic measurement, surface inspection and two-dimensional image digitization.

NUMEVISION cameras are designed around CCD image sensors, which are solid-state linear sensors offering a precise geometry, high dynamic range with anti-blooming feature, linearity of grey levels, stable performance and long life. The simultaneous exposure of all sensor pixels avoids distortion of moving objects. Encased in a rugged industrial housing, NUMEVISION cameras are available in four different resolutions up to 3456 pixels. Every camera incorporates an A/D converter which directly digitizes the sensor signal to eliminate signal degradation.

Each camera is controlled by a dedicated PC-compatible interface board, and additional PC-compatible boards are available for real-time image analysis and gradient pre-processing. NUMEVISION subsystems also incorporate a library of driver routines to develop application programs under DOS in C, FORTRAN, PASCAL, and BASIC. Source codes are also available to adapt the software to other environments.

g. Image Technology Methods (ITM) Corporation

ITM provides SOFCAM and DATAVISION high performance video cameras [57-63]. The ITM SOFCAM analytical video camera system is designed and featured to permit the casual computer operator, unfamiliar with video camera adjustment technology, to set up, command and control sophisticated sensing functions from the computer station. With SOFCAM, a line inspector can reliably execute acceptance tests for critical materials and precision components with little or no specialized training.

When the adaptive control provided by the SOFCAM cameras is not necessary, DATAVISION cameras provide identical mode selection and processing adjustments. DATAVISION systems have been used as manually controlled cameras for real-time metrology in industrial applications.

h. Imaging Technology, Inc.

Imaging Technology Incorporated is a supplier of image processing boards, modular subsystems, and software development tools for machine vision and image analysis applications for factory and laboratory environments [64]. Image processors are compatible with industry standards ATbus, Micro Channel, S-bus, and VMEbus-based computers, giving the flexibility of building the vision system using personal computers or powerful RISC-based workstations.

Imaging Technology's software capabilities provide the tools necessary to integrate vision systems, without learning the details of the image processing hardware. Every Imaging Technology hardware is supported by ITEX, a standardized library of image processing functions. Pattern recognition and object analysis functions are available in C language for the vision system application.

Over 100 third-party software packages, cameras, monitors, and other hardware peripherals are compatible with Imaging Technology's products.

i. Matrox Electronic Systems, Ltd.

Matrox's imaging product line consists of the PIP, the IP-8 frame capture and display controller for the PC AT and compatibles, the MVP-AT (MATROX Vision Processor) for real-time imaging on the IBM PC AT, and the IMAGE SERIES family of image processing boards and software tools for the AT or EISA bus architecture [73].

All products support a wide range of cameras and bus platforms such as AT bus, MCA, EISA bus, VMEbus and Multibus. An extensive library of "C" callable image processing, acquisition, graphics, and system control routines reduces the development time. Typical applications are defect detection, pattern recognition, gauging and part identification.

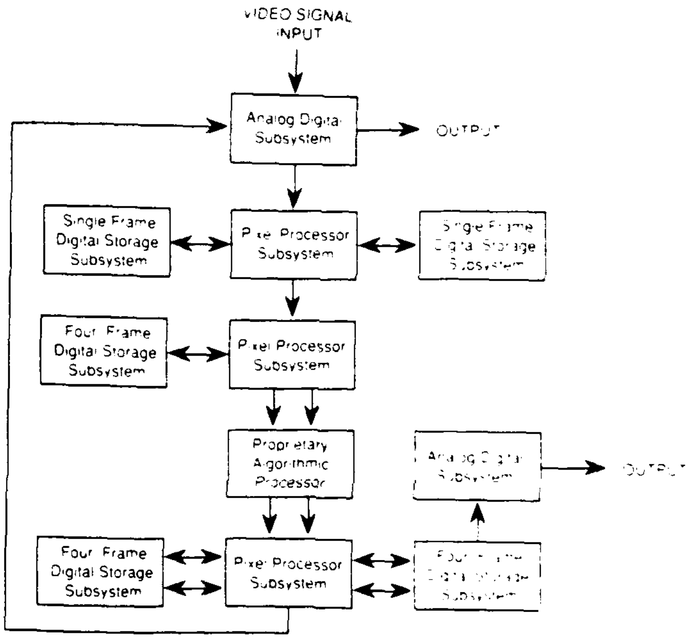

Figure 10 Recognition Technology, Inc. (RTI) Machine Vision System

k. Recognition Technology, Inc.

The RT5000 Series of machine vision systems from Recognition Technologies features hardware and software support for a variety of industrial and scientific applications. RTI units are currently being used in manufacturing inspection and process control, pattern recognition and defense research and development.

RTI provides complete integration and support services for clients needing turnkey applications. RTI systems provide high speed, high resolution gray scale vision, compatibility with RS-170 and CCIR video signals from cameras, VCRs and analog laser videodiscs.

RTI systems can use at least seven different hardware modules to implement vision applications. These modules include: An A/D-D/A unit for image acquisition and display, 512 by 512 pixel by 9 bit dynamic digital storage units, pipeline pixel processors for rapid image math functions, histogram/feature extractor units for intensity and (x,y) coordinated based functions, high speed look up table module, multimaster bus-to-bus translator units for host computer interface and pattern recognition/feature vector analyzer unit with onboard CPU for advanced metrology tasks. RTI systems have a significant integration of board-level image analysis for high speed processing applications.

RTI systems are supplied with the Vision Development Library (VDL) that offers over 1000 C callable routines. All RTI units operate with a host CPU, usually under MS-DOS or Unix, that issues commands to control vision hardware.

RTI has a customer base that includes United Technologies, Pratt and Whitney, NASA Lewis Development Center and the Marshall Space Center, the U.S. Air Force, Gillette and DARPA. A total of 200 measurement applications have been installed by RTI using a base of standard system software. U.S. Surgical uses a system to measure the dimensions of surgical steel staples. Gillette has installed 60 RTI systems on their new line to measure the blades on "Sensor" razors.

2.5.3 Material Qualification

Material qualification figures most prominently in the requirements for fastener qualification. Most methods for qualifying fasteners can be time-consuming and potentially destructive testing of sample parts. In the design philosophy of the proposed system, a limited technical inspection of a part returned to the depot should offer a fast, non-destructive means of evaluating the material properties of parts.

Electromagnetic comparators from Magnetic Analysis Corporation [76] provides this capability. Comparators are used to generate an electrical signal that corresponds to the difference between the composition of a reference specimen and a part being tested. Typically, the kinds of mixes that comparators will separate are variations in alloy, heat treatment, hardness, structure, dimensions, and certain kinds of cracks.

When a metal part is placed inside or near a coil which is excited by an alternating current, the voltage output from the coil will be affected. The effect that the part has on the output of the coil is directly related to the permeability, conductivity and physical dimensions of the part.

The voltage output of the coil may be affected in three different ways. The first is amplitude which is a change in the magnitude of the voltage output. The second is a change in the phase which is a change in the time relation of the output voltage. The third is harmonic distortion which occurs when high power is used on ferrous material to nearly saturate the part. This is usually an excellent way to indicate differences in core hardness.

The Production Comparator V is a versatile test instrument which uses low frequency electromagnetic techniques to inspect magnetic materials for variations in physical characteristics such as alloy, heat treatment and case depth.

The VARIMAC III eddy current comparator is designed for high speed sorting of magnetic or non magnetic parts into two or three groups based on differences of alloy, hardness, case depth, grain size, processing variations, plating thickness, dimension and orientation. Varimac instruments have found broad application in the fastener, ball bearing, chain and other small parts manufacturing industries (Figure 11).

In this application, a reference specimen of steel will be used as a base line comparison for all other materials. Each type of material, ferrous or non-ferrous, heat-treated or not heat-treated will give a characteristic output when it is placed in the measurement coil and compared to the reference specimen.

2.5.4 Plating and Coating Qualification

A practical fastener management system must consider plating and coating in the quality characterization of the part. Some of the non-contact techniques for characterizing plating include x-ray fluorescence, microresistance, eddy current and beta backscatter. X-ray fluorescence offers the ability to both identify the type of coating on a part and its thickness. The x-ray fluorescence system consists basically of an x-ray tube and a proportional counter. Emitted photons ionize the gas in the counter tube proportional to their energy, permitting spectral analysis for determination of the material and thickness.

The XRF-1000 Series from CMI International (Figure 12) offers state-of-the-art instrumentation, computer hardware and software packages for coating characterization and thickness measurement [27]. The XRF-1000 Series easily handles single and multiple coating measurements (simultaneously), such as nickel over steel, or aluminum and gold/nickel over copper. It measures thickness and composition of binary alloys (i.e. tin-lead over copper) simultaneously as well.

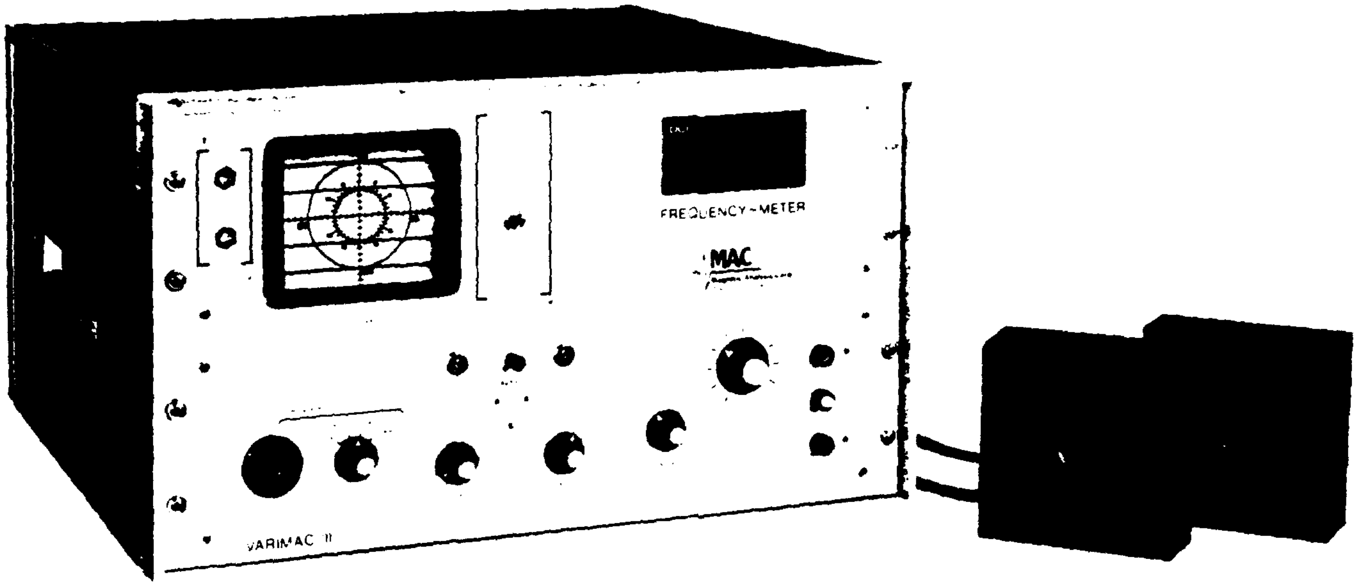

Figure 11 VARIMAC III

A PC-AT compatible computer provides all the speed necessary to run CMI or any MS-DOS software with ease. Compatible with MS-DOS permits ease interface with the fastener management system software. A fully integrated mouse simplifies program operation even for novice operators.

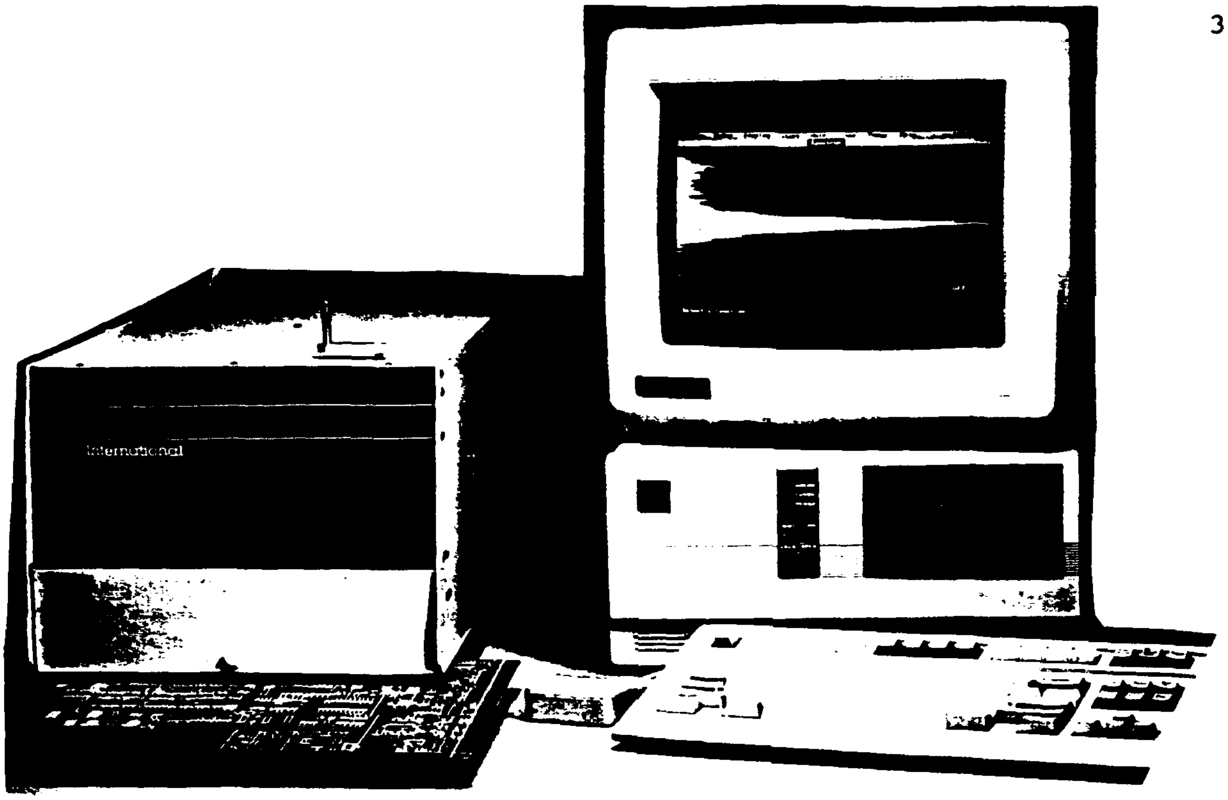

Figure 12 XRF-1000 Series

2.5.5 Databases

The DoD inventory has been effectively encoded in a variety of different database software systems. Commercial software such as Haystack and Parts-Master contain equivalent information of the Identification List (IL) and Federal Item Logistics Data Record (FILDR) on CD-ROM storage. They provide rapid parametric searches for an specific part. Parametric searching is a technique that uses parameters from a component (dimensions, material, etc.) to identify the NSN for that component. The limitation in these type of data resources is the quality of the information that is used to create the database. The entries in these type of commercial databases is only as good as the records maintained by the information source, in this case, the Defense Logistics Services Center (DLSC).

a. Information Handling Services HAYSTACK System

Is a comprehensive source of information on government purchased and stocked parts through the entire Federal Supply Catalog System. Figure 13 shows a typical HAYSTACK Search screen [65, 66].

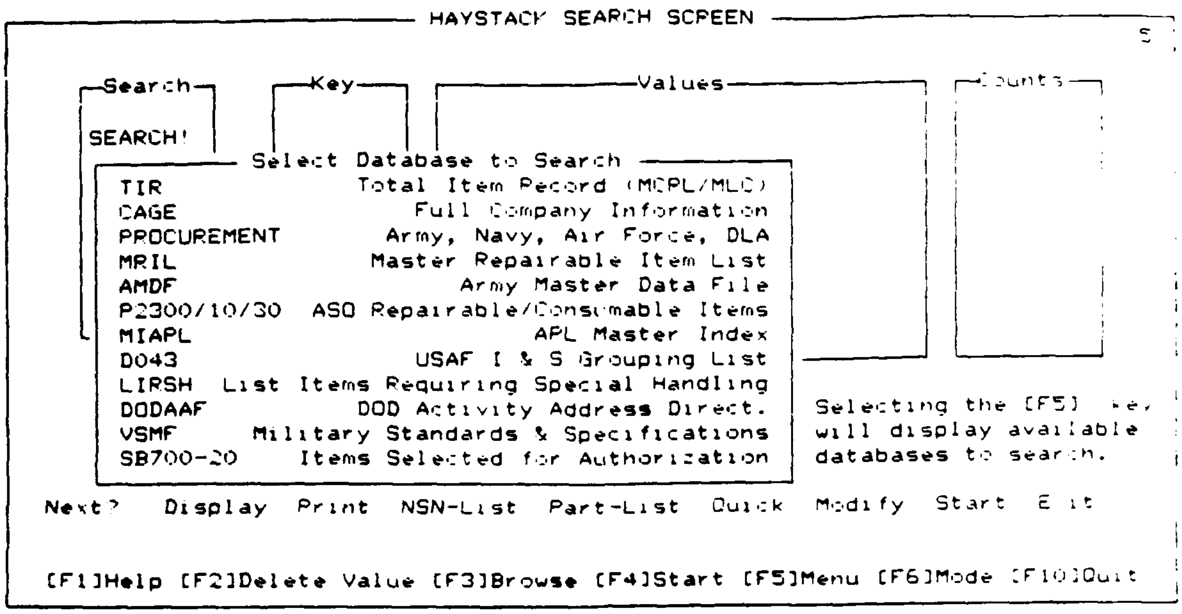

Figure 13 HAYSTACK System

b. National Standards Association PARTS-MASTER

PARTS-MASTER is a logistics support system on compact disks, it includes technical characteristics with parametric searching, procurement histories, CAGE and NSNs [75]. Figure 14 shows a typical display of the technical characteristics for a part searched on the database.

```
------------------- TECHNICAL CHARACTERISTICS -------------------
ITEM NAME CODE:  04905
THREAD CLASS:  3A
THREAD DIRECTION:  RIGHT-HAND
THREAD LENGTH:  0.508 INCHES NOMINAL
FASTENER LENGTH:  4.828 INCHES NOMINAL
HEAD STYLE:  C3
HEAD HEIGHT:  0.350 INCHES NOMINAL
WIDTH BETWEEN FLATS:  0.935 INCHES NOMINAL
SHOULDER DIAMETER:  0.624 INCHES NOMINAL
SHOULDER LENGTH:  3.970 INCHES NOMINAL
NOMINAL THREAD DIAMETER:  0.500 INCHES
THREAD QUANTITY PER INCH:  20
MINIMUM TENSILE STRENGTH:  240000 POUNDS PER SQUARE INCH
SHOULDER SHAPE:  ROUND
MATERIAL:  STEEL COMP 4340
MATERIAL DOCUMENT AND CLASSIFICATION:  MIL-S-5000 MIL SPEC SINGLE MATERIAL
 RESPONSE
SURFACE TREATMENT:  CHROMIUM
THREAD SERIES DESIGNATOR:  UNF
  * (ENTER) NEXT SCREEN * (BACKSPACE) PREVIOUS SCREEN * (ESCAPE) MAIN MENU *
```

Figure 14 PARTS-MASTER System

3. Discussion

3.1 Summary of Investigation (Major Accomplishments)

a. A comprehensive bibliography of documents has been compiled and reviewed that are related to DOD Internal Audits, Congressional Hearings and commercial information on fastener quality and inventory control issues.

b. A technology assessment effort was conducted that included contact with commercial and government sector accreditation organizations. This assessment is vital since the relevant legislation for the control of fasteners sold in commerce in the United States, PL 101-103 (Fastener Quality Act), requires inspection by accredited laboratories. The relevant accrediting bodies of the American Association for Laboratory Accreditation (A2LA), the American Society of Mechanical Engineers (ASME) and the National Institute for Standards and Technology (NIST) have been contacted. In addition, key contacts and literature in the fastener standards and inspection area have been collected.

c. Four site visits were made to Defense Depots (Defense Depot Region East (DDRE) and Defense Depot Region Central (DDRC)). The actual operation of the fastener receiving inspection, inventory and storage process were seen firsthand in a variety of settings. These trips permitted in-depth discussion with distribution, quality and receiving inspection personnel. Personnel in the Directorate of Quality demonstrated some of the techniques used for in-depth fastener receiving inspection. The site visit provided a perspective on the diversity of facilities in the Depot system where the proposed technology development effort could ultimately be targeted.

d. A post-award meeting was conducted at the University on September 9, 1991. Representatives from the University (Research, Administration and Accounting Personnel), DLA/DESC (CO), DLA-PRM (COTR) and ONRRR (ACO). All aspects of the contracting and accounting procedures were discussed.

e. A briefing was conducted at DLA-PRM Manufacturing Research Office in Cameron Station. This briefing allowed an opportunity to review of the results of the investigation to date, plan additional site visits and present the proposed Phase II investigation strategy. The meeting included Donald F. O'Brien, Chief, DLA Manufacturing Engineering Branch.

f. A site visit was made to Defense Distribution Region East (DDRE) where demonstrations were conducted of some of the hardware intended for the proposed Phase II effort. Two pieces of the proposed system were demonstrated independently to Distribution and Quality directorate personnel. Thomas Leone, CMI International, was present to demonstrate his company's XRX system for plating identification and thickness measurement. The system uses a personal computer based X-ray fluorescence system to identify the composition of metallic coatings and their thickness. Considerable interest on the part of DDRE personnel was generated. A Magnetic Analysis Corporation Verimac III eddy current comparator was also demonstrated to identify various metallurgical conditions corresponding to fastener grades.

g. Proper paperwork and personnel contacts were made at the Defense Technical Information Center (DTIC) to facilitate the acquisition of research documents. This represents a large time-savings potential since it is difficult to identify the source for many DOD documents.

h. A Phase II technical and cost proposal has been prepared. The technical plan uses various non-destructive evaluation tools coupled with an inventory database to produce a powerful aid for receiving inspectors to verify the accuracy of new procurement and identify potentially misidentified customer returns. This prototype system will be limited to threaded fasteners with heads. A depot site that has been investigated (DDRE) is targeted as a beta-test site for the technology.

3.2 Analysis of Site Visit Results

Numerous insights into the real problems of the depot handling of fasteners and the procurement process were gained as a result of the investigative site visits. In some cases, the information that was collected was very limited by several factors. In the first trip to DDRE there was no opportunity to observe incoming material inspection or unknown material identification. This aspect of depot operations is critical to the Phase II research. The tour of the facility during this first visit was highly structured and did not permit a close survey of the problems associated with material management (fasteners in particular). The DDRE facility is not representative of all depot operations since it is highly modernized and has received at large amount of investment and management attention. Consequently, it was necessary to return to the DDRE facility to better understand the receiving inspection/identification process. Furthermore, this visit motivated a need to see an older, less updated depot facility to obtain a view of the full spectrum of depot operations.

The follow-up visit to DDRE was very productive in understanding receiving inspection and identification operations. After meeting with the area supervisors, several hours were available to work directly with the receiving inspectors. The limited information that is available to the inspectors and the difficulty of using the microfiche and on-line computer data resources (Identification List (IL) and Federal Item Logistics Data Record (FILDR)) were observed. Inspectors must handle new procurement and customer returns. Frequently, these packages frequently have limited or improper markings. The inspector must verify that the item corresponds to the contract number and that it is in usable condition. The inspectors have a few simple measurement tools (caliper and thread gage) to verify the conformability of thousands of different fasteners. Plating type, material composition and geometry (beyond overall size) are impossible to verify. In addition, most inspectors receive no technical training other than working with a more experienced inspector. *Critical decisions are made about millions of dollars in hardware with little or no objective support.*

It is clear that some technical support tools could have an enormous impact on curbing misidentified material, material designated for disposal and material non-conformance. A sensing system that can determine major dimensions, plating and metallurgy could be integrated with commercially available federal supply software (e.g., Haystack and Partsmaster). Such a system could dramatically improve the effectiveness of the receiving inspection process and create a cost saving by avoiding disposal and misidentified hardware. A source at DDRE indicated that recent audit revealed that as much as 2% of their inventory may be misidentified.

During the follow-up visit to DDRE, the Director of Distribution, made some observations about the receiving inspection process. There was a general agreement that technical support tools should be available for receiving inspection personnel, but he noted that part of the problem is due to the lack of schools to train receiving inspectors. He recommends training programs offered by supply centers for each major commodity type.

The investigation has revealed that improving the technical support tools for receiving inspection at depots can have a large impact on the problems of handling fasteners in the DLA inventory. Inspectors must handle new procurement and customer returns. Both forms of shipment often require the inspector to verify that the item corresponds to the contract number and that it is in usable condition. As discussed previously, the inspectors have a few simple measurement tools to verify the conformability of thousands of different fasteners. Plating type, material composition and geometry are often impossible to quantify. As a result, the identification of an item is very tedious, if not impossible. Many receipts are either misidentified and placed in inventory or targeted for disposal.

The site visit to DDRC was very productive in understanding the wide range of facilities in the DLA Depot system and the associated receiving inspection and identification operations. After meeting with the area supervisors, several hours were available to work directly with the receiving inspectors. The typical procedure employed by receiving inspectors was followed in attempting to verify the technical characteristics of new procurement and accurately identifying customer returns. As witnessed at DDRE, the limited information that is available to the inspectors and the difficulty of using the microfiche data resources (Identification List (IL) and Federal Item Logistics Data Record (FILDR)) were observed.

It must be noted that the operations at DDRC do not incorporate the bar code data marked on all packages processed in the facility. As a consequence of the limited availability of bar code automation, the receiving inspection operation does not appear to be as efficient as those witnessed at DDRE. The contract number data contained in the bar code or LOGMAR are hand-keyed into the receiving inspector's terminal to the central inventory system. The on-line data resources to the Defense Logistics Services Center (DLSC) are available at each inspection station, but they are characteristically slow and, according to operating personnel, subject to downtime.

The general operation of the DDRC facility was the same as was seen at DDRE, inspectors must handle new procurement and customer returns. Frequently, the observed packages had limited or improper markings. Theoretically, the inspector must verify that the item corresponds to the contract number and that it is in usable condition. As was the case at DDRE, the inspectors have a few simple measurement tools (caliper and thread gage) to verify the conformability of thousands of different fasteners. Consequently, plating type and material composition are impossible to verify.

This site visit has further clarified the need for technical support tools for receiving inspection. This particular site visit also illustrated the need for simplicity and robustness of the system in order for it to gain acceptance in an environment with limited automation. Observation of receiving inspection personnel suggested that the available microfiche data resources were not frequently used in the material identification process. As previously described, the proposed system could have an enormous impact on curbing misidentified material, material designated for disposal and material non-conformance.

Directorate of Distribution personnel at DDRC repeatedly observed that all receiving inspection personnel could perform all required verification and identification tasks if adequate labor was assigned to the task. They recommended more personnel for receiving inspection and training programs offered by supply centers for different commodities.

The hardware demonstration at DDRE in December was useful for obtaining the potential user reaction to the proposed Phase II system. A significant number of Distribution and Quality directorate personnel were on hand to view the hardware and ask questions about its potential use. The hardware seemed to fill a gap in the available receiving inspection capabilities. The coating identification capabilities of the X-ray fluorescence technology seemed to be of particular interest. The demonstration included the "real-world" scenario of material being pulled directly from receiving inspection and identified/verified for plating or metallurgy. This activity was intended to illustrate the robustness and simple operation of the proposed hardware.

3.3 Analysis of Technology Survey Effort

The site visits at defense depots have shown that inspectors must handle new procurement and customer returns with limited technical tools. Each inspector checks between 20 to 25 receiving packages per day, where a large number of these packages have limited or improper marking having the inspector to make some type of decision on the fitness of the item.

The inspector must verify that the item corresponds to the contract information and that it is in usable condition. Only few simple measurements tools (for example, caliper and thread gage) are used to verify the conformability of thousands of different fasteners. Plating type, material composition and geometry (beyond overall size) are impossible to verify. The difficulty of using the microfiche and on-line computer data resources (Identification List (IL) and Federal Item Logistics Data Record (FILDR)) and the lack of technical training that most of the inspectors have, make this task even more arduous. Critical decisions are made about millions of dollars in hardware with little or no objective support.

It is clear that some technical support tools could have an enormous impact on curbing misidentified material, material designated for disposal and material non-conformance. A sensing system that can determine major dimensions, plating and metallurgy could be integrated with commercially available federal supply software, improving the effectiveness of the receiving inspection process. The proposed plan for Phase II of the investigation calls for the integration of available technologies in a user friendly environment.

The survey effort has suggested that an imaging system from Recognition Technology, Inc. (RTI) is the most suitable for providing non-contact dimensional inspection of fasteners at high speed without operator intervention. The equipment uses a CCD camera and hardware-based image processing. The unit operates with a host CPU under MS-DOS that issues the commands to control the vision hardware. RTI system is supplied with the Vision Development Library (VDL) to develop the geometric inspection software. The advantage in using RTI is the company's experience, installation base and capabilities of providing complete integration and support services in turnkey applications.

The VARIMAC III eddy current comparator from Magnetic Analysis Corporation has been selected to perform the metallurgical validation of receiving fasteners. The instrument is designed for metallurgical sorting of magnetic or non magnetic parts and have found broad application in the fastener, ball bearing and other small parts manufacturing industries. Grade 8 parts will be used as the comparison standard. The system will be interfaced to an IBM compatible computer using standard hardware from Data Translation. MAC equipment was tested in our laboratory providing excellent results.

This investigation has identified the x-ray fluorescence plating inspector from CMI International as the best alternative for plating characterization and thickness measurement. The system easily handles single and multiple coating measurements and the hardware is based on an IBM compatible computer providing ease interfacing with the fastener management system software. A fully integrated mouse simplifies the program operation even for novice operators. The equipment was tested both in our laboratory and by receiving inspectors at DDRE/EDC New Cumberland, showing a high degree of acceptance by the personnel.

The technology above described can provide parametric data input into the PARTS-MASTER electronic logistic support system from National Standards Association. The CD-Rom database can identify a contract number, flag non-conforming material or avoid the unnecessary dispcsal of costly components. The system runs on an IBM compatible computer and has been tested with demonstration diskettes in our facilities.

This technology will be prototyped for use with threaded fasteners with heads, but extensions could be made to other commodities where the cost savings could be even more substantial. Technical inspection and verification tools for commodities with limited shelf life (o-rings, medical equipment, etc.) would have a potentially greater cost saving since there is a less time available to properly identify and inventory these items.

4. Recommendations

4.1 Technical Approach

There is a large potential cost savings that could result from supplying technical tools to aid in the receiving inspection process. A starting point for a technical tool to improve this process is an efficient data resource for the parts in the inventory. The DLA inventory has been effectively encoded in a variety of different database software systems. Commercial software such Haystack and Partsmaster have been evaluated as part of this investigation.

These tools contain the equivalent of the FILDR and IL on CD-Rom storage technology and provide for rapid parametric searches for specific contracts. For example, all contract numbers for cap screws with a two inch overall length can be found in a matter of seconds. All technical characteristics from the IL for each item can be retrieved and quickly compared to other available data to rapidly identify a specific part. Again, such data resources are limited by the accuracy and completeness of the information provided for their compilation. However, this type of on-line database represents the best available technology.

The database capabilities of the software described above is useless without the proper parametric data. Technical tools for identifying metallurgy, plating and geometry have been identified for potential integration into the database system. For example, a table-top fluorescence scanner (such as the XRX series from CMI International) can readily provide an almost 100% accurate means of identifying types of plating. Similar eddy current devices can pinpoint metallurgical composition. An economical inspection aid can be assembled to quickly and accurately identify the technical data associated with a particular fastener. This data can provide parametric data input into a CD-Rom database and identify a National Stock Number, flag non-conforming material or avoid the unnecessary disposal of costly components. Ultimately, as manufacturer's insignia and other headmarkings become increasingly standardized and commonplace, the system should be able to use vision system technology to read these symbols and determine if there are correct for the given specimen.

4.2 Phase II Research

The proposed plan for Phase II of this research effort calls for the development of a tool to improve the receiving inspection process for fasteners at depots. The corresponding proposal *Development of a Receiving Inspection Item Identifier/Validator* serves as an appendix to this report. The proposed technology development can have a significant impact on the problems of handling fasteners in the DLA inventory. Inspectors must handle new procurement and customer returns. Both forms of shipment often require the inspector to verify that the item corresponds to the contract number and that it is in usable condition. As discussed previously, the inspectors have a few simple measurement tools to verify the conformability of thousands of different fasteners. Plating type, material composition and geometry are often impossible to quantify. As a result, the identification of an item is very tedious, if not impossible. Many receipts are either misidentified and placed in inventory or targeted for disposal. There is a large potential cost savings that could result from supplying technical tools to aid in the receiving inspection process. The DoD inventory has been effectively encoded in a variety of different database software systems.

These technologies can be assembled into a system to quickly and accurately identify the technical data associated with a particular fastener. This data can provide parametric data input into a CD-Rom database and identify a National Stock Number, flag non-conforming material or avoid the unnecessary disposal of costly components. **This technology will be prototyped for use with threaded fasteners with heads, but extensions could be made to other commodities where the cost savings could be even more substantial.** Technical inspection and verification tools for commodities with limited shelf life (o-rings, medical equipment, etc.) would have a potentially greater cost saving since there is a less time available to properly identify and inventory these items.

The proposed plan for Phase II of the investigation calls for the development of tools to improve the receiving inspection process for fasteners at depots. The proposed hardware technology requirements are:

1. <u>CMI Fluorescence Plating Inspector</u>
   Provides positive indication of plating type and thickness. Uses X-Ray fluorescence principles to analyze metals and metal coating. The method is insensitive to plating chemicals, base metal part cleanliness. The hardware is based on an IBM computer platform.

2. <u>MAC Varimac Eddy Current Sensing System</u>
   Provides non-destructive metallurgical properties sensing. Uses eddy current comparison techniques. Sensing output is amplitude and phase proportional of the inducted current in the test sample. Grade 8 parts will be used as the comparison standard. The system requires an analog input card to permit interface to an IBM compatible computer platform. Standard interface hardware from Data Translation will be used.

3. <u>RTI Imaging System</u>
   Provides non-contact dimensional inspection of small parts. Uses a CCD camera and hardware-based image processing. Major dimensions and features will be extracted from the fasteners at high speed without operator intervention. The system is based on an IBM compatible bus architecture.

4. <u>Parts-Master Electronic Logistics Support System</u>
   Provides procurement histories, technical characteristics and parametric searching on the Defense Supply System. The technology includes five compact discs updated monthly, five compact disc readers, controller board and software on floppy discs. The hardware is based on an IBM compatible computer.

5. <u>Specialized Feature Extraction - Inventory Search Software</u>
   Provides the fusion of various sensor data to perform the parametric searching on the Parts-Master database. The software will be completely developed by our group and will act as the brain of the Receiving Inspection Item Identifier/Validator.

The proposed system is shown schematically in Figure 15. The objectives of this Phase II technology development effort are to provide an efficient, user friendly receiving Inspection identification/validation system for threaded fasteners with heads. The prototype system for

Phase II will be a limited implementation where the operator chooses the headtype of the fastener from a graphical menu to limit the amount of fixturing and/or cameras that are necessary to perform the identification and verification tasks. The system will feature integrated technologies that are *transparent* to the user. The system will offer a rapid, independent means of improving the critically important job of the receiving inspector.

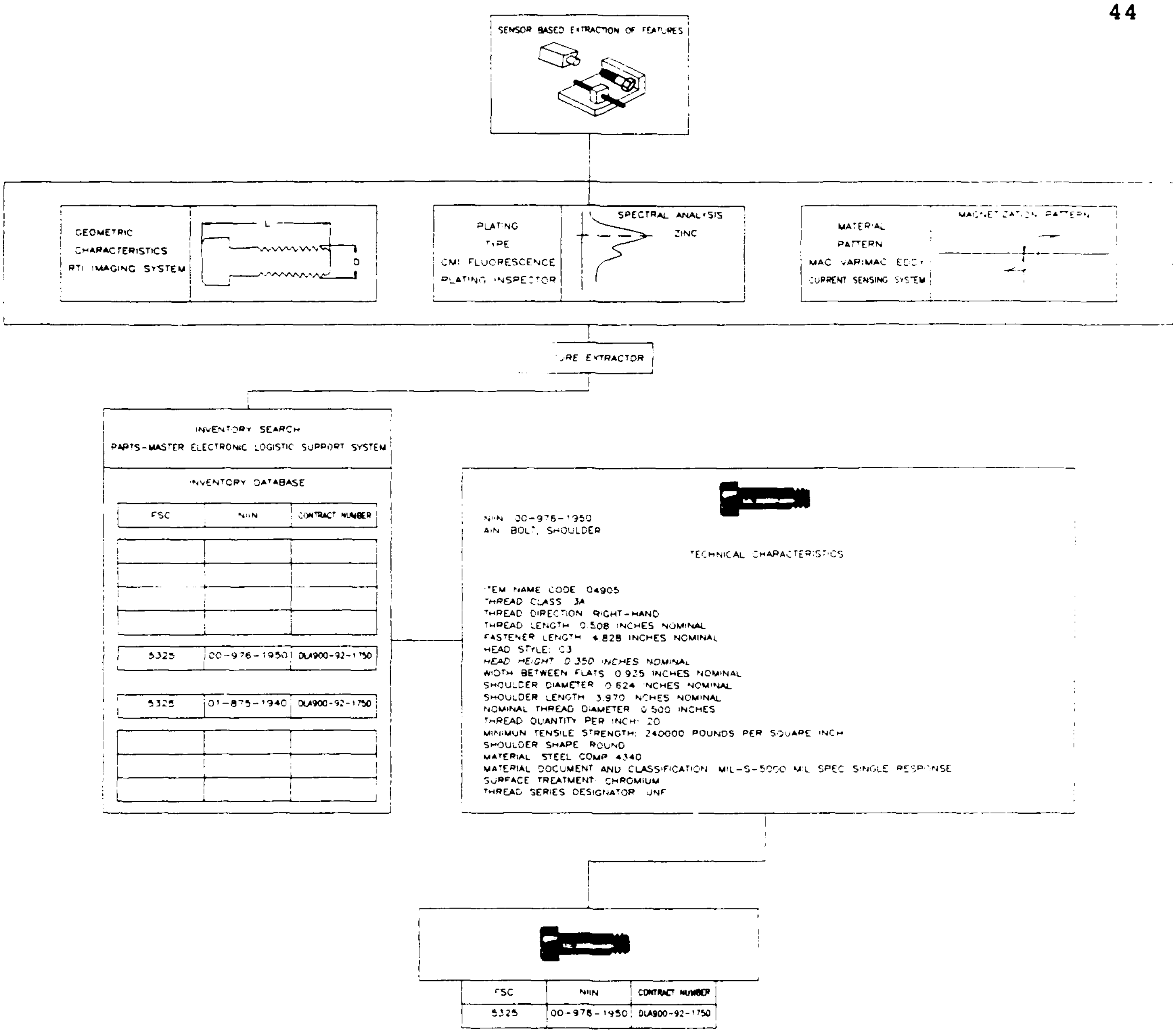

Figure 15 Proposed Phase II Technology Development: Receiving Item Identification/Validation System

The system will be site tested at DDRE/EDC New Cumberland using receiving inspection personnel previously interviewed and identified as capable and willing to participate in this technology development effort. The development program calls for a four month beta test site evaluation in the depot. This will provide an opportunity for customer feedback and system enhancement. Ultimately, the debugged prototype system could be placed into production for regular use.

The proposed Phase II system has two functions, item identification and item validation. It is proposed that these functions be enhanced in a Phase III development to offer a self-learning, adaptive database and a item reduction function. The Phase III system will include two vision cameras to simultaneously image the profile and head of the fastener. This system will use specialized pattern recognition software to identify the grade and manufacturers insignia on the part and provide these additional parameters for identification and validation. The system database will also be adaptive, it will develop new entries for parts that are not yet included in the existing database. In this way, the tool is a *learning system* capable of acquiring new, yet unseen components into its database. Finally, the Phase III system will recommend potential item reductions, recalling which differently numbered items have the same parameters and periodically generating a recommended item reduction report.

The Phase II development has a variety of benefits for the DLA as it is implemented. It offers a potential cost savings in reduced product disposal, product deficiency reports and new contract orders to replace disposed or misidentified material. This development program is strictly a prototyping effort. In order to attain the desired savings on a large scale, the *technology must be transferred to industry*. An appropriate vendor (such as IHS and NSA, the suppliers of the CD-Rom data resources) can offer extensions to other commodities, continuous improvement, larger scale cost savings and, ultimately, improved efficiency for DLA depot operations.

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